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Comparison of sunspot area data determined from ground-based and space-borne observation

L. Győri[1], T. Baranyi[2], J. Muraközy[2], and A. Ludmány[2]

[1] Heliophysical Observatory, Gyula Observing Station, 5701 Gyula, P.O. Box 93, Hungary
e-mail: ls@bekesnet.hu
[2] Heliophysical Observatory, 4010 Debrecen, P.O. Box 30, Hungary

Abstract. The measurement of the area of sunspots is important from the point of view of study of sunspots and their effect on solar irradiance. Large number of solar images is now available from both terrestrial and space observations. Sunspot areas from different databases derived by using different image sets and programs are compared in this paper.

Key words. Sun: sunspot area – Sun: heliographic coordinates

1. Introduction

The area and position data of sunspots are important in different fields of solar physics, e.g., emergence, growth, and decay of spots; evolution of the sunspot groups and interaction between them; axial tilt and rotation rate of the groups; periodicity in solar activity; fragmentation of flux tubes; solar irradiance variations.

Automated sunspot area measurements are now replacing time-consuming and subjective hand-made measurements. Also, terrestrial solar observations have been supplemented by observations from space. The resolution of the ground observations is limited by the seeing, while space-borne observations are limited by the size of the CCD array. The use of different data sources, as well as of different region identification algorithms, causes differences in reported sunspot areas. An important task is to determine to what extent these differences can be attributed to different analysis methods and to what extent to different data.

Send offprint requests to: L. Győri

2. Observations and Data

In this paper we compare two full-disk image series. One of them is the SOHO/MDI images (1024x1024 pixel) obtained as proxies for the continuum intensity near the Ni-I absorption line at 676.8 nm by combining the standard five filtergrams (Scherrer at al. 1995). The other image set contains daily ground-based photoheliograms taken to film or glass plates gathered from several observatories (Gyula, Debrecen, Kanzelhoehe, Kislovodsk, etc.), which are used in the compilation of the Debrecen Photoheliographic Data (DPD) catalogue (Győri et al. 2004).

From these two image series four sunspot databases are derived by three feature recognition techniques. SAM is a set of cooperative computer programs, developed at Debrecen Heliophysical Observatory, that embraces every aspect of compiling a sunspot catalogue: from (1) setting up the necessary data basis for the observation and the telescope, (2) automatically detecting sunspots (umbra and penumbra) on solar images and determining their heliographic coordinates and area through (3) making the catalogue ready for printing (Győri 1998). SAM is used to compile the DPD catalogue which has 1 observation/day time resolution.

Recently a similar sunspot catalogue compilation has been started by using SAM and the SOHO/MDI continuum (Ic) images. It is called SOHO/MDI- Debrecen Data (SDD) catalogue (Győri et al. 2005). We use the Full Disk Continuum images from the hourly data sets level 1.8. This catalogue will be similar to that of DPD in its data format and image products but the time cadence is 1 hour when SOHO/MDI observations allow it. The first year (1996) is ready and we use it to compare its sunspot areas with other databases.

At University of Bredford (Zharkov et al. 2003, Benkhalil et al. 2003, Fuller & Aboudarham 2004) an automated recognition of sunspots on solar images was also developed and used to produce the Solar Feature Catalogue (SFC).

Another technique called StarTool (ST) and based on Bayesian Pattern Recognition methods was developed by Turmon et al. (2002) and applied to SOHO/MDI images.

Both these data sets have max. 4 observations/day time resolution.

3. Areas: SAM - StarTool

In two previous papers (Győri et al. 2002, Győri et al. 2004b) we compared three types of sunspot areas: (1) DPD areas derived by SAM from ground-based observations, (2) MDI/ST areas derived by StarTool from SOHO/MDI images, and (3) MDI/SAM areas derived by SAM from SOHO/MDI images that was prepared by ST.

The equation and residual RMS of the regression line fitted to MDI/ST and DPD/SAM areas are:

$$A_{\mathrm{MDI,ST}} = 1.37 A_{\mathrm{DPD,SAM}} + 264 \quad (\chi = 217). \quad (1)$$

From Eq. (2) we find that MDI/ST areas are larger by 37% than that of DPD/SAM.

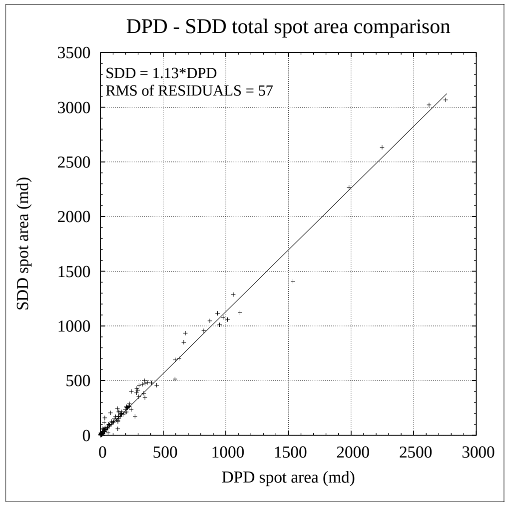

Fig. 1. SDD sunspot (umbra + penumbra) area (in millionth of the solar disk) summed up on the whole disc versus DPD area.

The equation and residual RMS of the regression line fitted to DPD/SAM and MDI/SAM areas are:

$$A_{\mathrm{MDI,SAM}} = 1.14 A_{\mathrm{DPD,SAM}} \quad (\chi = 75). \quad (2)$$

Eq. (2) shows that MDI/SAM areas are larger by 14% than that of DPD/SAM.

The equation and residual RMS of the regression line fitted to MDI/SAM and MDI/ST areas are:

$$A_{\mathrm{MDI,ST}} = 1.20 A_{\mathrm{MDI,SAM}} + 233 \quad (\chi = 208). \quad (3)$$

Eq. (3) shows that MDI/ST areas are larger by 20% than MDI/SAM areas.

4. Areas: DPD - SDD

As mentioned before SAM has been already applied to MDI images but then these images has been preprocessed (flat-fielded, corrected for limb darkening, corrected for ellipticity, disk center and radius determined) by StarTool. Now the image preprocessing has been done by SAM. Figure 1 and 2 show the comparison of SDD sunspot areas with that of DPD. Comparing Figure 1 and Eq. (2) we can see that the results are nearly the same.

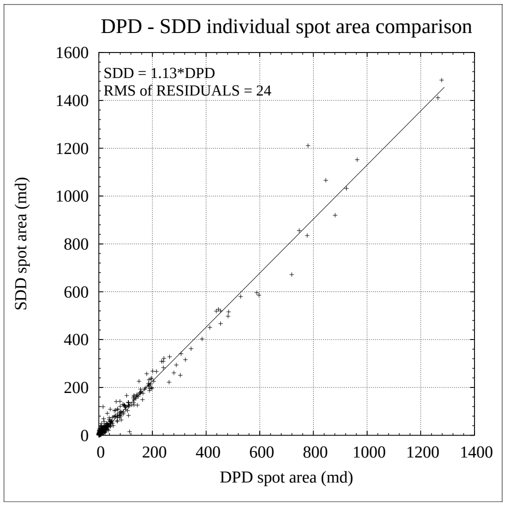

Fig. 2. SDD individual (identified) sunspot (umbra + penumbra) area (in millionth of the solar disk) versus DPD area.

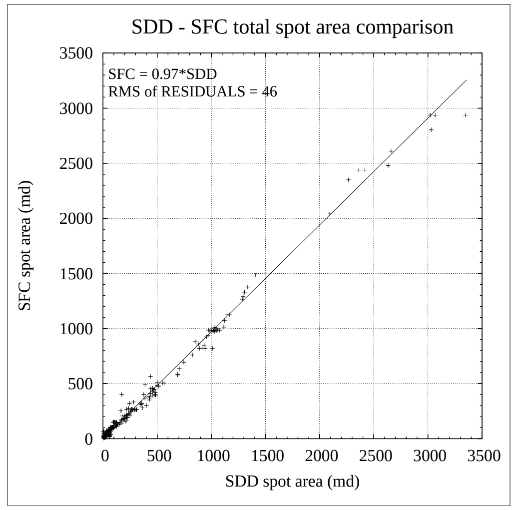

Fig. 3. SFC sunspot (umbra + penumbra) area (in millionth of the solar disk) summed up on the whole disc versus SDD area.

5. Areas: SDD - SFC

Figure 3 and 4 show the comparison of SFC sunspot areas with that of DPD. In Figure 3 we can see that SDD and SFC total spot areas (daily sums, on the whole disc, of the umbra + penumbra areas) agree well. SFC total spot areas are a bit smaller by 3%. A part of that small discrepancy can be explained by the fact that the number of sunspots per image in SFC is fewer by 2 in average than in DPD. But the situation is not so good when we compare umbra areas. In this case, SFC areas are larger by 31% as Figure 5 shows it.

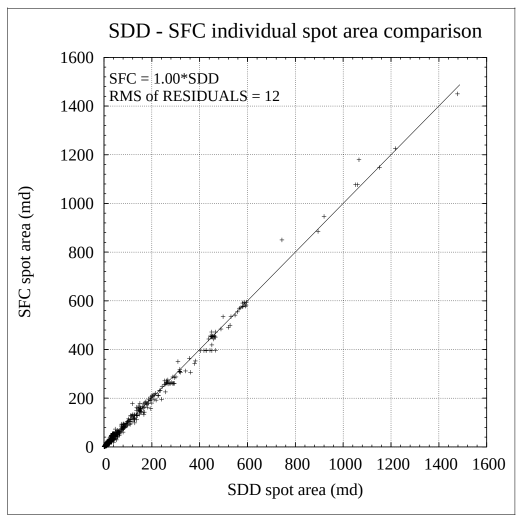

Fig. 4. SFC individual (identified) sunspot (umbra + penumbra) area (in millionth of the solar disk) versus SDD area.

6. Conclusions

We compared sunspot areas derived by different image processing techniques from different images.

SDD and SFC areas are larger by 13% than DPD areas. This discrepancy can be attributed to the smaller scale of the SOHO/MDI images as it was discussed by Győri et al. (2004b) . The SOHO/MDI image size is 1024x1024 pixels while the image size used when scanning DPD images is about 7500x7500 pixels.

When SAM and the SFC program are applied to the same MDI images, there is a good agreement in total sunspot areas obtained. We have a small (3%) systematic difference and some random scatter (46 md). However, the SFC program gives larger total umbra area by 31% than SAM. Both techniques make use of the gradient image (edge map) derived from the solar image. But the details of the exploit-

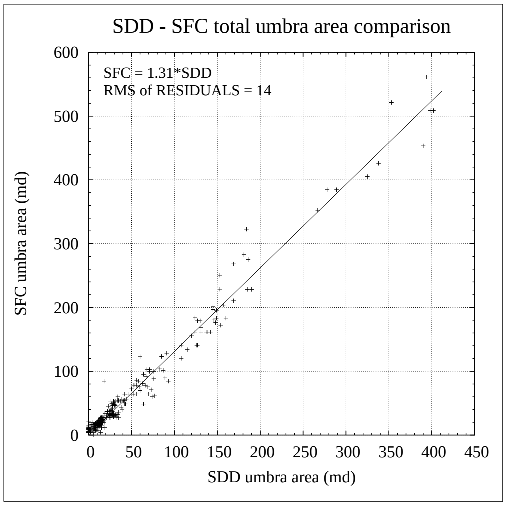

Fig. 5. SFC umbra area (in millionth of the solar disk) summed up on the whole disc versus SDD umbra area.

ing the gradient image to get the spot boundaries (umbra and penumbra) are very different in the two methods. It seems that these differences do not essentially influence the finding of the penumbra border but in the case of the umbra (which is generally less well defined) become significant.

These investigations can be regarded as preliminary studies because they are only based on about half a year (1996) of the sunspot minimum and so the number of data is relatively small. In the future, we will repeat this study on a larger data set.

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